Modification to Special Relativity

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Abstract

The speed of light is usually taken as one of the fundamental constants. String, and field, theories appear to require the altercation of this constant into a functional form $E(m,c)$ which is not $E = mc^2$. The analysis requires the re-interpretation of the renormalization group flow equations. There are quantum corrections to the mass-energy relation generically for particles of any sort. A breakdown of special relativity follows. Cosmological data might be one of the best testbeds to analyze the computable functional forms of the mass energy relations.

Introduction

Special relativity [1] has been one of cornerstones of modern physics for over a hundred years. The notion of on-shellness for a particle or string is used to define quantum scattering processes through a simple classical propagator; propagators dont have to be simple to be consistent with basic symmetries however. The renormalization group has been fully integrated with special relativity. This work is primarily dedicated to theories that do not require taking a renormalization limit, such as string models or quantum field models that are effective theories.

A physical interpretation of the renormalization group, together with its consistency, does require that the energy relation $E(m, c)$ be a function derived in a specific quantum field theory; furthermore in the case of light or gravity this function tells us that $c(E)$, or that the speed of light varies from our currently accepted value c_0, the value specified in true vacuum.

The use of the relevant n-point functions define the masses and couplings through their bare values,

$$m^2(m_0^2, \lambda_0^{(j)}; E, c; \Lambda) \qquad \lambda^{(j)}(\lambda_0^{(j)}; m_0^2; E, c, \Lambda) \ , \tag{1}$$

and Λ here is the string coupling constant, or a UV cutoff in field theory; there could be moduli associated with the compactified space and the fluxes which have not been included. The masses and couplings are fixed in energy; if they run, then the running can be specified in the left hand side of (1). The latter case is not examined, but could be with certain running to match experimental data. The functional form is inverted to find $c(E, m; m, \lambda^{(j)})$. Of course, higher dimension operators may be added to change the functional form of the mass-energy relation to model the latter case. After finding the functional form, it is substituted or reshuffled back into the n-point functions with higher dimension operators (add and subtract) to determine the full scattering.

These equations usually are called renormalization equations [2], and are not used in string theory except for calculations which are renormalization special; such as three point functions in which phase space requires all momenta to be zero, or to cancel IR divergences in the S-matrix rather than then the calculation of the full cross section which will cancel IR divergences. The equation for the couplings, e.g. 3-pt, 4-pt, . . ., are not specifically the renormalization group form, as a sum has been performed. For example, the terms $A^2\Box A^2$ and $A^2\Box^2 A^2$ have been grouped together

in one function in k-space rather than separated as is typical in RG. Also, note that on-shell requires $k^2 = m^2$, by definition.

The naive substitution of $E = mc_0^2$ might not be consistent with (1). Note that c_0 is used here and in (1) the correct value c is used. An example function is not difficult to find; the bare values of m_0 are used but the argument can also be obtained with the observed vales m. Holding m, m_0 fixed (with $\lambda_0^{(j)}$) could generate a function $1 = \sin^2 E/c^2/m_0 f(k^2/m_0^2)$ which would generate $E = m_0 c^2 g(k^2/m_0^2)$. This function, as m_0 is typically large, varies with the momenta. Although the couplings, including the masses, are included there is self-consistency that requires the speed of light to change. This is canceled by changing the renormalization by scaling the RG point for example. This scaling of the parameters m_0 and $\lambda_0^{(j)}$ would restore consistency with special relativity. String theory doesn't have a UV renormalization point and the conclusion is that the speed of light must be a function of energy.

The renormalization equations (1) for the photon and graviton generate the equations (with a massless $m = 0$),

$$c_p(E) \qquad c_g(E) \ . \tag{2}$$

The h-bar is not used but emphasizes the functional dependence of the speed of light and energy, which is quantum due to the flow equations,

$$c = \sum c_j E'^j \tag{3}$$

in terms of the plank energy $E' = E/\beta$. The β parameter as the length scale is not used in terms of compactified dimensions as these moduli might flow also.

The equations in (1) should be consistent with eachother, including the mass and couplings. Note that these functions m and $\lambda^{(j)}$ represent the infinite number of terms of the particular scattering of the the vertices with independent couplings. In the two-point function there is one momenta. The entire sum contributes to the relations in (1).

One consequence of the variability of the speed of light is that there are an infinite number of quantum corrections to the energy-mass relation, as in (3). Another consequence is that special relativity has been violated although not in a strong manner because only one dimension, time, is essentially treated differently. This implies a special reference frame. Furthermore, there may be zeros in $c_p(E)$ and

$c_g(E)$; in the case of gravity this would require quantization in the pseudo-topological teleparallel formalism.

Each species of particle would have its own $E(c, m)$ relation with the zeroth order being its own $E = m_0 c_0^2$ relation. The similarities of the various particles would in turn express similarities of their quantization, and the structure of spacetime, including the compactification.

Energy is defined via the field and string theoretic notion of a Hamiltonian and its action of flows in time on states. Varying the definition of energy could alter the energy mass relation; this could lead to a closer pairing at least in practical definition of mass and energy.

The variation of the speed of light or gravity range from zero to very large values including infinity, and perhaps is somewhat periodic in energy due to a fixed mass parameter and its integer multiples. Cosmological data might want to be re-examined for clues to these dispersion relations, both in light and gravity, especially in experimental evidence where there are either large energies, such as in supernovae, or when energy scales radically fluctuates in short time periods so that the dispersion can be seen next to a peak along a very steep slope. Also, data generated by groups experimentally testing special relativity could hold clues within their precision and energy range.

References

[1] Albert Einstein Annelen der Physik **17**, pp.891 (1905).

[2] K.G. Wilson and John B. Kogut, Phys. Rept. **12**:75-200,1974.